Poster Presentations

HEAD-TRUNK MOTION INCREASE WITH ARM-REST CONTROLS

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Introduction

Heavy equipment manufacturers have made a long-term commitment to minimize operator vibration exposure for comfort, performance, and health reasons. Domestic and international guidelines/standards and EC laws dictate exposure limits based on measurement of vibration at the interface between the seat and the operator's buttocks using seat-pad accelerometry.[1-4] This is historically based on the assumption that the only major source of vibration is transmitted through the seat pan. However, vibration may also be imparted to the head and neck via the steering wheel and/or arm-rest controls and a relatively rigid upper body.[5] Unfortunately, little is known regarding the influence of arm position on head and neck motion. The purpose of this study was to investigate relative head and trunk motions during riding simulations of large construction equipment, using three different arm control options.

Methods

Five typical heavy equipment ride files were "played back" through a man-rated Servo Test 6-degree-of-freedom vibration system. An 8-camera Vicon motion capture system operating at 200 frames per second, recorded the motion of reflective surface markers on 5^{th}, 50^{th}, and 95^{th} percentile right-handed male subjects, using 3 seat and control configurations (steering wheel (SW), floor mounted armrest controls (FM), seat-mounted armrest controls (SM)). Two trials were performed for each ride and seat control combination (each trial: 60 sec of 6-dof and 60 sec of vertical vibration). The relative motions (change in distances) from the marker over the xiphoid process (caudal end of sternum) to markers over each shoulder, each mid-clavicle, the presternal notch, and to each of four markers on a tight band around the head were calculated (12,001 frames, 6-dof motion only). As a rigid body control, distances between markers on the head band were also monitored. The standard deviation (SD) of the 12,001 distances between pairs of markers was normalized by the mean (L) of the associated distances producing: SD/L which was used as a measure of motion. Error assessments were also performed by analyzing the motion between relatively fixed markers (on the headband). A repeated measures analysis of variance was used to evaluate the results. While five ride files were used, only one ride file containing significant lateral acceleration components was analyzed for comparing the effects of two armrest controls versus use of a steering wheel for this part of our study.

Results

Values of SD/L between the points on the relatively rigid head band were consistently small and similar to each other for all conditions with one exception due to treatment (SM v SW, $p=0.0145$). SD/L between the markers over the xiphoid process and the presternal notch, another region that should be relatively rigid, were also similar to each other for all conditions. Use of floor-mounted, arm rest controls versus a steering wheel produced a significant increase in the value of SD/L between the xiphoid process and: the right shoulder marker (92%, $p=0.0316$), the right mid-clavicle marker (47%, $p=0.0478$), and the right-front marker on the head band (28%, $p=0.0182$). Use of floor-mounted, arm rest controls versus seat-mounted, arm rest controls produced a significant increase in the value of SD/L between the xiphoid process and the right-back marker on the head band (14%, p=0.0467).

Discussion

During a pilot study to assess the efficacy of a motion capture system in whole-body vibration studies, the authors observed a large increase in head-trunk relative motion due to the use of armrest controls, raising a concern about an increased likelihood of injuries. With the use of a steering wheel, the trunk and arms can behave as active dampers, attenuating horizontal motions and maintaining a stable platform for the head-neck system (an inverted pendulum). Armrest controls more rigidly couple the shoulders, via the upper arms, to a vibration source and bypass the damping provided by the entire arm, potentially increasing the risk of motion-related musculoskeletal problems in the neck and upper trunk. While armrests may reduce arm and shoulder fatigue and reduce the effect of the vibrating trunk mass on the lower back, they may do so at the expense of increased motion at the neck and shoulders. The vibration community needs to consider the effect of and attenuation of vibration from sources other than the seat pan. The authors urge the standards and law making communities to consider vibration sources in addition to those at the operator's seat pan.

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